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Updated to 2016-18 Syllabus

CIE IGCSE PHYSICS 0625

SUMMARIZED NOTES ON THE EXTENDED SYLLABUS

TABLE OF CONTENTS

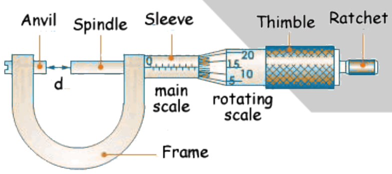
1. Length and Time

1.1 Length

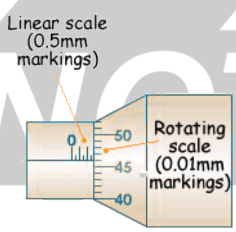
- A rule (ruler) is used to measure length for distances between 1mm and 1meter
- SI unit for length is the meter (m)
- To find out volume of regular object, use mathematical formula
- To find out volume of irregular object, put object into measuring cylinder with water. When object added, it displaces water, making water level rise. Measure this rise. This is the volume.

1.2 Micrometer Screw Gauge

- Used to measure very small distances
- Determination of the diameter 'd' of a wire



- Place the wire between the anvil and spindle end as indicated in the diagram.
- Rotate the thimble until the wire is firmly held between the anvil and the spindle.
- The ratchet is provided to avoid excessive pressure on the wire. It prevents the spindle from further movement - squashing the wire
- To take a reading:
  - First look at the main scale. This has a linear scale reading on it. The long lines are every millimetre the shorter ones denote half a millimetre in between.
  - On the diagram this reading is 2.5 mm
  - Now look at the rotating scale. That denotes 46 divisions - each division is 0.01mm so we have 0.46mm from this scale.
  - The diameter of the wire is the sum of these readings:
  - 2.5 + 0.46 = 2.96 mm



1.3 Time

- Interval of time is measured using clocks
- SI unit for time is the second(s)
- To find the amount of time it takes a pendulum to make a spin, time ~25 circles and then divide by the same number as the number of circles.

2. Motion

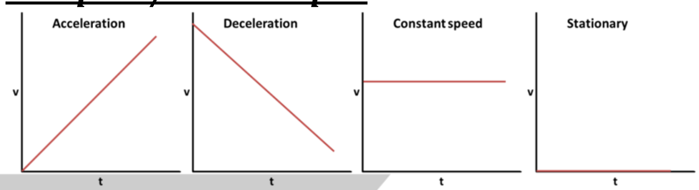
2.1 Speed

- Speed is the distance an object moves in a time frame. It is measured in meters/second (m/s) or kilometers/hour (km/h).

$$Speed = \frac{Total\ Distance}{Total\ Time}$$

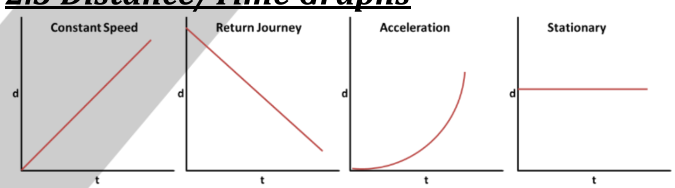
- Speed is a scalar quantity

2.2 Speed/Time Graphs



- Area under the line equals to the distance travelled
- $Gradient = \frac{y_2 - y_1}{x_2 - x_1}$ = =Acceleration (m/s)^2

2.3 Distance/Time Graphs



- $Gradient = \frac{y_2 - y_1}{x_2 - x_1}$= Speed (m/s)

2.4 Distance

- Calculating distance travelled:
  - With constant speed: $Speed \times Time$
  - With constant acceleration: $\frac{Final\ Speed + Initial\ Speed}{2} \times Time$

2.5 Acceleration

$$Acceleration = \frac{Final\ Speed - Initial\ Speed}{Time\ Taken}$$

- Acceleration is the rate of change in velocity per unit of time, measured in meters per second, or m/s^2
- Acceleration is a vector quantity
- Positive acceleration means the velocity of a body is increasing
- Deceleration or negative acceleration means the velocity of a body is decreasing
- If acceleration is not constant, the speed/time graph will be curved.
- The downwards acceleration of an object is caused by gravity. This happens most when an object is in free.

- Objects are slowed down by air resistance. Once air resistance is equal to the force of gravity, the object has reached terminal velocity. This means that it will stay at a constant velocity. acceleration of free fall for a body near to the Earth is constant (G=10m/s)

3. Mass and Weight

- Mass: amount of matter an object contains, and is a property that 'resists' change in motion
- Weight is the force of gravity acting on an object, measured in Newtons, and given by the formula:

$$Weight = Mass \times Gravity$$

- Weights (and hence masses) may be compared using a balance

4. Density

$$Density = \frac{Mass}{Volume}$$

- Density of a liquid: place measuring cylinder on a balance, fill measuring cylinder with the liquid. The change in mass is mass of liquid and volume is shown on the scale, then use formula.
- Density of solid:
  - Finding the volume: To find out volume of a regular object, use mathematical formula. To find out volume of an irregular object, put object into a measuring cylinder with water and the rise of water is the volume of the object
  - Finding the mass: weigh object on a scale and use formula

4.1 Flotation

- The density of water is 1g/cm^3, if an object has a greater density than that, then it will sink in water, and if the object's density is less than that, then it will float in water.
- **Example:** an orange with its peel has a density of 0.84g/cm^3, we can predict that it will float because it is less than 1 g/cm^3. We can also say, that an orange without its peel, which has a density of 1.16g/cm^3, will sink because it is greater than 1g/cm^3.

5. Forces

5.1 Effects of Forces

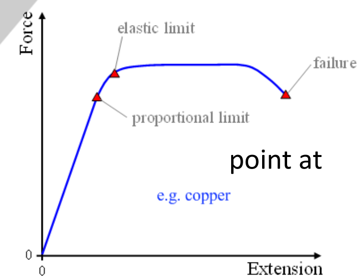
- A force may produce a change in size and shape of a body, give an acceleration or deceleration or a change in direction depending on the direction of the force.
- If there is no resultant force acting on a body, it either remains at rest or continues at constant speed in a straight line

5.2 Friction

- **Friction:** the force between two surfaces which impedes motion and results in heating
- Air resistance is a form of friction

5.3 Hooke's Law

- Springs extend in proportion to load, as long as they are under their proportional limit.
- Limit of proportionality: point at which load and extension are no longer proportional



- Elastic limit: point at which the spring will not return to its original shape after being stretched

$$Load(N) = Spring\ Constant \times extension$$
$$F = ke$$

5.4 Forces

- Forces measured in Newtons

$$Force = Mass \times Acceleration$$

- 1 Newton is the amount of force needed to give 1kg an acceleration of 1m/s^2

5.5 Circular Motion

- An object at steady speed in circular orbit is always accelerating as its direction is changing, but it gets no closer to the center
- Centripetal force is the force acting towards the center of a circle. It is a force that is needed, not caused, by circular motion,
- For example, when you swing a ball on a string round in a circle, the tension of the string is the centripetal force. If the string is cut then the ball will travel in a straight line at a tangent to the circle at the point where the string was cut.

- Centrifugal force is the force acting away from the center of a circle. This is what makes a slingshot go outwards as you spin it. The centrifugal force is the reaction to the centripetal force. It has the same magnitude but opposite direction to centripetal force.

$$F = \frac{mv^2}{r}$$

5.6 Newton's Laws

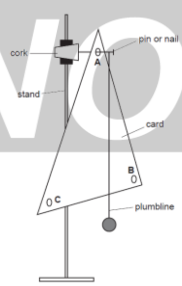
- First law of motion: If no external for is acting on it, an object will, if stationary, remain stationary, and if moving, keep moving at a steady speed in the same straight line
- Second law of motion: $F = ma$
- Third law of motion: if object A exerts a force on object B, then object B will exert an equal but opposite force on object A

5.7 Moment

$$Moment(Nm) = Force(N) \times Distance\ from\ Pivot(m)$$

- In equilibrium, clockwise moment = anticlockwise moment.
- Increasing force or distance from the pivot increases the moment of a force
- Levers are force magnifiers
  - Turning a bolt is far easier with a wrench because distance from pivot is massively increased, and so is the turning effect

5.8 Centre of Mass



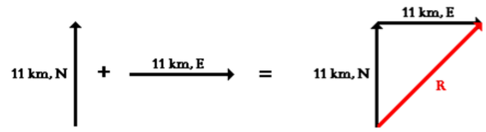
- Centre of mass: imaginary point in a body where total mass of body seems to be acting
- Working out the center of mass:
  - Mark three points on the edge of the card
  - Make a hole using a pin on each point
  - Hang it on a cork board and make a line when it is stable
  - Do this for all three points
  - Where all three lines intersect, this is the center of mass

5.9 Stability

- An object will be in stable equilibrium when it returns to its original position given a small displacement
- For an object to start rotating it needs to have an unbalanced moment acting on it

5.10 Scalars and Vectors

- A scalar is a quantity that only has a magnitude (so it can only be positive) for example speed.
- A vector quantity has a direction as well as a magnitude, for example velocity, which can be negative.



$11^2 + 11^2 = R^2$

$242 = R^2$

$15.6 = R$

6. Momentum

- **Linear momentum:** product of mass and velocity

$$p = mv$$

- **Principle of conservation of linear momentum:** when bodies in a system interact, total momentum remains constant provided no external force acts on the system.

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

- **Impulse:** product of force and time for which it acts

$$Ft = mv - mu$$

7. Energy, Work, and Power

7.1 Energy

- **Energy:** amount of work and its measured in Joules (J)
- An object may have energy due to its motion or its position
- Conservation of energy: energy cannot be created or destroyed, when work is done, energy is changed from one form to another
- Energy can be stored

ENERGY TYPE	WHAT IT IS	EXAMPLE
KINETIC	Due to motion	Car moving
GRAVITATIONAL	From potential to fall	Book on shelf
CHEMICAL	In chemical bonds	Bonds in starch (food)
STRAIN	Compress/stretch	Stretched elastic band
NUCLEAR	Atoms rearranged/split	Released in nuclear plant
INTERNAL	Motion of molecules	In a glass of water
ELECTRICAL	Carried by electrons	Battery to bulb
LIGHT	Carried in light waves	From sun
SOUND	Carried in sound waves	From speaker

$$Kinetic\ energy = {}^1/_2 \times Mass \times Velocity^2$$

$$K.E. = {}^1/_2\, mv^2$$

$$Graviational\ Potential\ Energy = Mass \times Gravity \times Height$$

$$G.P.E. = mgh$$

- Example of conversion of energy: A book on a shelf has g.p.e , if it falls of the shelf it will have k.e

7.2 Energy Resources

- Renewable sources are not exhaustible
- Non-renewable sources of energy are exhaustible

TYPE	ADVANTAGES	DISADVANTAGES
Fuel: burnt to make thermal energy, makes steam, turns turbine	• Cheap • Plentiful • Low-tech	• Harmful wastes: ○ Greenhouse/ pollutant gas ○ Radiation
Wave energy: generators driven by up and down motion of waves at sea.	• No greenhouse gases produced	• Difficult to build
Tidal energy: dam built where river meets sea, lake fills when tides comes in & empties when tide goes out; water flow runs generator	• No greenhouse gases produced	• Expensive • Can't be built everywhere
Hydroelectric: river & rain fill up lake behind dam, water released, turns turbine ∴ generator	• Low impact on environment • Energy produced at constant rate	• Few areas of the world suitable
Geothermal: water pumped down to hot rocks rising as steam	• No CO_2 produced	• Deep drilling difficult and expensive
Nuclear fission: uranium atoms split by shooting neutrons at them	• Produces a lot of energy with very little resources	• Produces radioactive waste
Solar cells: made of materials that deliver electrical current when it absorbs light **Solar panels:** absorbs energy and use it to heat water	• No CO_2 produced	• Variable amount of sunshine in some countries

- The sun is the source of energy for all our energy resources except geothermal, nuclear and tidal
- In the sun, energy is created through a process called nuclear fusion: hydrogen nuclei are pushed together to form helium.
- Efficiency: how much useful work is done with energy supplied

$$Efficiency = \frac{Useful\ energy\ output}{Energy\ input} \times 100\%$$

$$Efficiency = \frac{Useful\ power\ output}{Power\ input} \times 100\%$$

7.3 Work

- Work is done whenever a force makes something move.
- The unit for work is the Joule (J).
- 1 joule of work = force of 1 Newton moves an object by 1 meter

$$Work\ done\ (J) = Force\ (N) \times Distance\ (m)$$

$$W = FD$$

7.4 Power

- Power is the rate of work
- The unit for power is Watts (W)
- 1W = 1J/s

$$Power\ (W) = \frac{Work\ Done\ (J)}{Time\ Taken\ (s)}$$

8. Pressure

8.1 Pressure in Solids

$$Pressure\ (Pa) = \frac{Force\ (N)}{Area\ (m^2)}$$

$$P = \frac{F}{A}$$

- Unit: Pascals (Pa) = N/m^2

8.2 Pressure in Liquids

$$Pressure(Pa) = Density(kg/m^3) \times Gravity(m/s^2) \times Height(m)$$

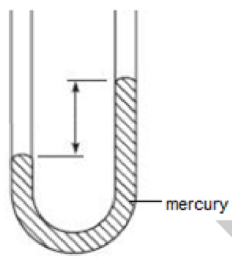
$$P = h\rho g$$

- At a depth of 10m in water, the pressure is always 100,000 Pa (1bar) and is constant for each further 10m.

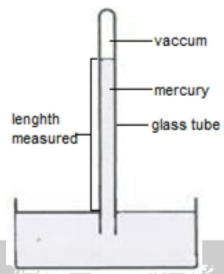
8.3 Atmospheric Pressure

- 1 atm = 101.325 X 10^3 Pa = 101 KPa

MANOMETER



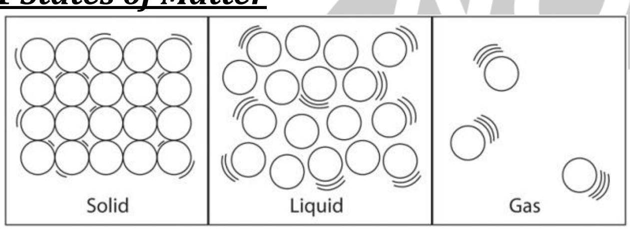
BAROMETER



• A manometer measures the pressure difference. • The height difference shows the excess pressure in addition to the atmospheric pressure.	• Tube with vacuum at the top and mercury filling the rest. • Pressure of the air pushes down on reservoir, forcing mercury up the tube. • Measure height of mercury • ~760 mm of mercury is 1 atm.

9. Simple Kinetic Molecular Model of Matter

9.1 States of Matter

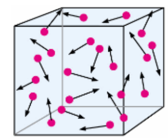


SOLID	LIQUID	GAS
• Fixed shape and volume • Strong forces of attraction between particles • Fixed pattern (lattice) • Atoms vibrate but can't change position ∴ fixed volume and shape	• Fixed volume but changes shape depending on its container • Weaker attractive forces than solids • No fixed pattern, liquids take shape of their container • Particles slide past each other.	• No fixed shape or volume, gases fill up containers • Almost no intermolecular forces • Particles far apart, and move quickly • Collide with each other and bounce in all directions

9.2 Pressure in Gases

- The pressure gases exert on a container is due to the particles colliding on the container walls.
- If the volume is constant, then increasing the temperature will increase the pressure.

9.3 Brownian Motion



- Gas molecules move at a random motion
- This is because of repeated collisions with other gas molecules
- Small molecules move much faster and have higher energy than larger molecules
- The small particles can help move the larger particles
- Brownian motion can be seen visually in smoke

9.4 Evaporation

- It is the escape of more energetic particles and occurs constantly on surface of liquids.
- If more energetic particles escape, liquid contains few high energy particles and more low energy particles so average temperature decreases.
- Evaporation can be accelerated by:
  - Increasing temperature: more particles have energy to escape
  - Increasing surface area: more molecules are close to the surface
  - Reduce humidity level in air: if the air is less humid, fewer particles are condensing.
  - Blow air across the surface: removes molecules before they can return to liquid

9.5 Pressure Changes

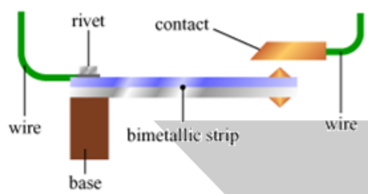
$$P_1V_1 = P_2V_2$$

10. Thermal Properties & Temperature

10.1 Thermal Expansion of Solids, Liquids & Gases

- Solids, liquids and gasses expand when they are heated as atoms vibrate more and this causes them to become further apart, taking up a greater volume.

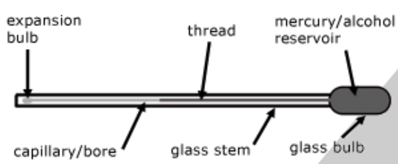
- Due to differences in molecular structure of the different states of matter, expansion is greatest in gases, less so in liquids and lowest in solids
- Applications and consequences of thermal expansion:
  - Overhead cables have to be slack so that on cold days, when they contract, they don't snap or detach.
  - Gaps have to be left in bridge to allow for expansion
  - Bimetal thermostat: when temperature gets too high, bimetal strip bends, to make contacts separate until temperature falls enough, then metal strip will become straight again and contacts touch, to maintain a steady temperature



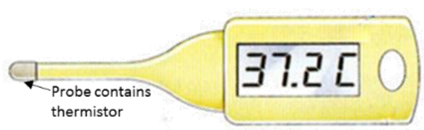
- For a fixed mass of gas at constant pressure, the volume is directly proportional to the Kelvin temperature

10.2 Measurement of Temperature

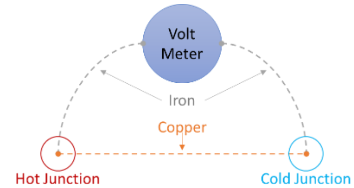
- A physical property that varies with temperature may be used for measurement of temperature
- **Liquid-in-glass thermometer:**



  - As temperature rises or falls, the liquid (mercury or alcohol) expands or contracts.
  - Amount of expansion can be matched to temperature on a scale.
- **Thermistor thermometer:**



  - The probe contains a thermistor
  - The thermistor is a material that becomes a better electrical conductor when the temperature rises (semi-conductor)
  - So when temperature increases, a higher current flows from a battery, causing a higher reading on the meter
- **Thermocouple thermometer:**



  - The probe contains 2 different metals joined metals to form 2 junctions.
  - The temperature difference causes a tiny voltage which makes a current flow.
  - A greater temp. difference gives a greater current.
  - Thermocouple thermometers are used for high temperatures which change rapidly and have a large range (-200C° to 1100°C)
- **Fixed points** are definite temperatures at which something happens and are used to calibrate a thermometer. For example, melting and boiling point of water
- **Calibrating a thermometer:**
  - Place thermometer in melting ice, this is 0 °C.
  - Place thermometer in boiling water, this is 100 °C.
- **Sensitivity:** change in length or volume per degree
- **To increase sensitivity:**
  - Thinner capillary
  - Less dense liquid
  - Bigger bulb
- **Range:** change the upper and lower fixed points
- **Linearity:** change the distance between intervals
  - **Responsiveness:** how long it takes for the thermometer to react to a change in temperature

10.3 Melting

- This is when a solid turns into a liquid.
- Temperature increases thus kinetic energy in solid increases and particles vibrate more rapidly but there is no increase in temperature of the substance when melting because thermal energy supplied is instead being used to break bonds between particles of the solid thus making it into a liquid.
- Boiling point is the temp. at which a substance boils

10.4 Boiling

- This is when a liquid turns into a gas
- Temperature increases thus kinetic energy in liquid increases and particles vibrate more rapidly but there is no increase in temperature of the substance when boiling because thermal energy supplied is instead being used to break bonds between particles of the liquid thus making it into a gas.

- Melting point is the temp. at which a substance melts
- The difference between boiling and evaporation is that:
  - Boiling occurs at a fixed temperature and throughout the liquid
  - Evaporation occurs at any temperature and only on the surface

10.5 Latent Heat

- The latent heat of fusion is the amount of energy needed to melt 1Kg of a substance.
- The latent heat of vaporization is the amount of energy needed to boil 1Kg of a substance

$$\text{Specific Latent Heat of Fusion/Vaporization} = \frac{\text{Energy Transferred}}{\text{Mass}}$$

$$L_f/L_v = \frac{E}{m}$$

10.6 Condensation and Solidification

- Condensation is when a gas turns back into a liquid.
- When a gas is cooled, the particles lose energy. They move more and more slowly. When they bump into each other, they do not have enough energy to bounce away again so they stay close together, and a liquid forms.
- When a liquid cools, the particles slow down even more. Eventually they stop moving except for vibrations and a solid forms.

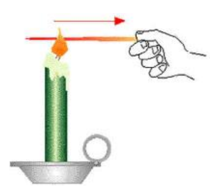
11. Thermal Processes

11.1 Conductors

- Good conductors are used whenever heat is required to travel quickly through something
- Bad conductors (insulators) are used to reduce the amount of heat lost to the surroundings

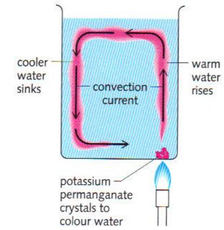
11.2 Conduction

- Conduction is the flow of heat through matter from places of higher temperature to places of lower temperature without movement of the matter as a whole



- In non-metals - when heat is supplied to something, its atoms vibrate faster and pass on their vibrations to the adjacent atoms.
- In metals – conduction happens in the previous way and in a quicker way –electrons are free to move, they travel randomly in the metal and collide with atoms and pass on the vibrations.

11.3 Convection



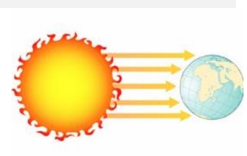
- Convection is the flow of heat through a fluid from places of higher temperature in places of lower temperature by movement of the fluid itself.
- As a fluid (liquid or gas) warms up, the particles which are warmer become less dense and rise.
- They then cool and fall back to the heat source, creating a cycle called convection current.
- As particles circulate they transfer energy to other particles. If a cooling object is above a fluid it will create a convection current

11.4 Radiation

- Radiation is the flow of heat from one place to another by means of electromagnetic waves
- Thermal radiation is mainly infra-red waves, but very hot objects also give out light waves. Infra-red radiation is part of the electromagnetic spectrum.

	MATT BLACK	WHITE	SILVER
EMITTER	Best		Worst
REFLECTOR	Worst		Best
ABSORBER	Best		Worst

- An emitter sends out thermal radiation.
- A reflector reflects thermal radiation, therefore is a bad absorber.



- An emitter will cool down quickly, an absorber will heat up more quickly and a reflector will not heat up quickly

11.5 Application of Energy Transfer

- Solar panel: the sun's thermal radiation is absorbed by a matt black surface and warms up the pipes containing water
- Refrigerator: the freezer compartment is located at the top of the refrigerator. It cools down the air which then sinks. Any warm air rises to the top and then is cooled. This creates a convection current which maintains a cold temperature.
- Metals used in cooking pans because they conduct heat well

11.6 Consequences of Energy Transfer

- Metal spoon in a hot drink will warm up because it conducts heat

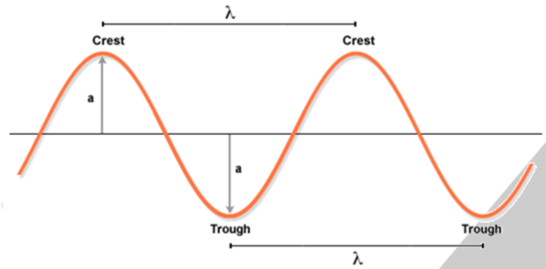
- Convection currents create sea breezes. During the day the land is warmer and acts as heat source. During the night the sea acts as the heat source.
- A black saucepan cools better than a white one, white houses stay cooler than dark ones.

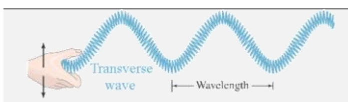
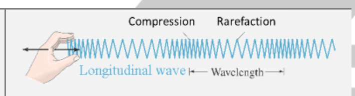
12. General Wave Properties

- Waves transfer energy without transferring matter
- **Frequency:** the number of waves passing any point per second measured in hertz (Hz)

$$\textit{Frequency} = \frac{1}{\textit{Period}}$$

- **Period:** time taken for one oscillation in seconds
- **Wavefront:** the peak of a transverse wave or the compression of a longitudinal wave
- **Speed:** how fast the wave travels measured in m/s
- **Wavelength:** distance between a point on one wave to the equivalent point on the next wave in meters
- **Amplitude:** maximum distance a wave moves from its rest position when a wave passes



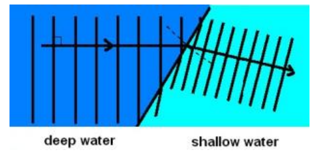
TRANSVERSE WAVES	LONGITUDINAL WAVES
	
• Travelling waves in which oscillation is perpendicular to direction of travel • Has crests and troughs • For example, light, water waves and vibrating string	• Travelling waves in which oscillation is parallel to direction of travel. • Has compressions and rarefactions • For example, sound waves

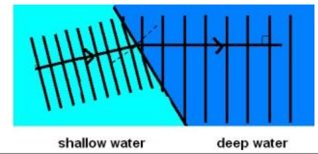
$$Speed\ (m/s) = Frequncy(Hz) \times Wavelength(m)$$

$$V = F\lambda$$

12.1 Refraction

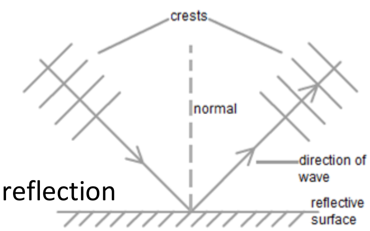
- Speed and wave length is reduced but frequency stays the same and the wave changes direction
- Waves slow down when they pass from a less to a more dense material and vice versa
- When wave is slowed down, it is refracted towards normal (i > r)
- When wave is sped up, it is refracted away from normal (i < r)
- Deep water is denser than shallow water





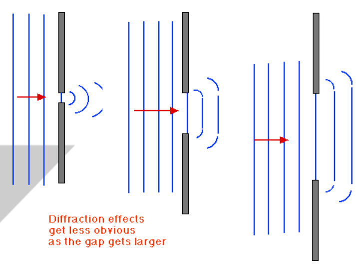
When water wave travels from deep to shallow; speed decreases, wavelength decreases and frequency remains constant	When water waves travel from shallow to deep; speed increases wavelength increases and frequency remains constant

12.2 Reflection



- Waves bounce away from surface at same angle they strike it
- Angle of incidence = angle of reflection
- Speed, wavelength and frequency are unchanged by reflection

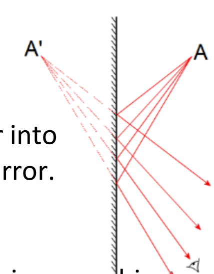
12.3 Diffraction



- Waves bend round the sides of an obstacle, or spread out as they pass through a gap.
- Wider gaps produce less diffraction.
- When the gap size is equal to the wavelength, maximum diffraction occurs

13. Light

13.1 Reflection of Light



- Plane (flat) mirrors produce a reflection.
- Rays from an object reflect off the mirror into our eyes, but we see them behind the mirror.
- The image has these properties:
  - Image is the same size as the object
  - Image is the same distance from the mirror as object
  - A line joining equivalent points of the image and object meet the mirror at a right angle
  - Image is virtual: no rays actually pass through the image and the image cannot be formed on a screen

- Laws of reflection:

Angle of incidence = angle of reflection

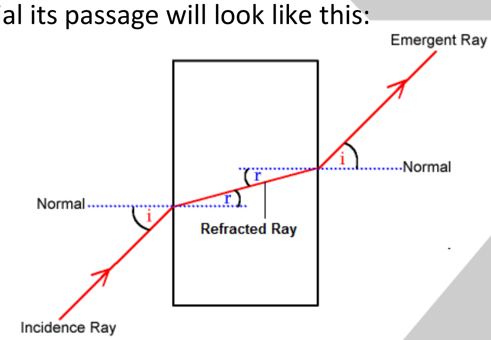
The incident ray, reflected ray and normal are always on the same plane (side of mirror)

13.2 Refraction of Light

- Refraction is the bending when light travels from one medium to another

13.3 Experimental Demonstration – Ray Box

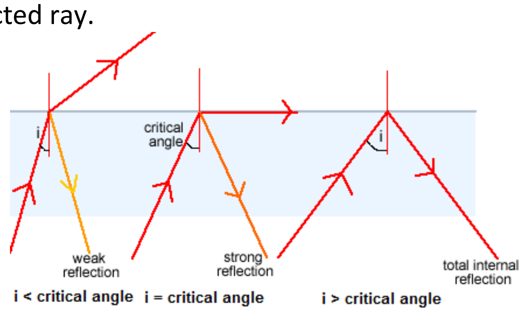
- Using the ray box, pass a ray through a glass slab on a white sheet of paper.
- Mark two points on the incident ray, refracted ray, emergent ray and draw an outline of the glass slab with a pencil on paper
- Then by connecting the dots you can produce a diagram like the one below, a protractor is used to find the angles.
- When a ray passes through a parallel sided transparent material its passage will look like this:



- **Note:** the emergent ray is parallel to the incident ray

13.4 Critical Angle

- Angle at which refracted ray is parallel to the surface of material.
- If angle of incidence is greater than the critical angle there is no refracted ray, there is total internal reflection.
- If angle of incidence is less than the critical angle the incidence ray will split into a refracted ray and a weaker reflected ray.



$$\textit{Refractive Index} = \frac{\textit{Speed of light in vacuum}}{\textit{Speed of lught in a medium}}$$

$$\textit{Refractive Index} = \frac{\sin i}{\sin r}$$

$$\textit{Critical angle} = \sin^{-1} {}^{1}/_{n}$$

13.5 Optical Fibres

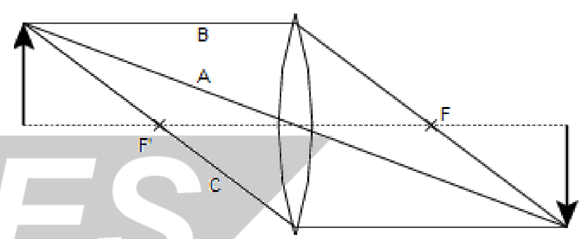
- Light put in at one end is totally internally reflected until it comes out the other end.
- Used in communications: signals are coded and sent along the fiber as pulses of laser light
- Used in medicine: an endoscope, an instrument used by surgeons to look inside the body; contains a long bundle of optic fibers.

13.6 Thin Converging Lens

- **Principal focus:** the point where rays parallel to the principal axis converge with a converging lens.
- **Focal length:** distance from principle focus and the optical center.
- **Principal axis:** line that goes through optical center, and the 2 foci.
- Optical cente**r:** the center of the lens
- **Real:** image can be caught on a screen
- **Virtual:** image cannot be caught on a screen

Real Image

- When object is further away from the optical centre than F' is



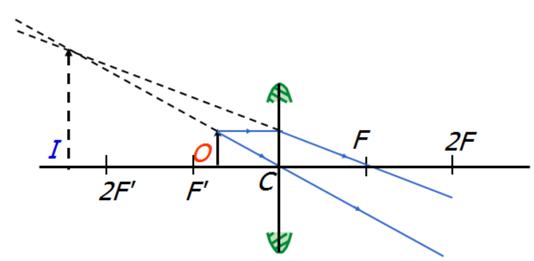
A) A ray through centre of the lens passes straight through the lens.

B) A ray parallel to the principal axis passes through the focus on the other side of the lens

C) A ray through F' will leave the lens parallel to the principal axis

Virtual Image

- When the object is closer to the optical centre than F' is

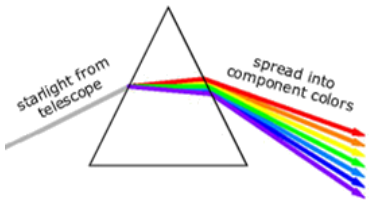


- **Magnifying glass:** when a convex lens is used like this - an object is closer to a convex (converging) lens than the principal focus (like the diagram above), the rays never converge. Instead, they appear to come from a position behind the lens. The image is upright and magnified, it is a virtual image.

13.7 Dispersion of Light

Refraction by a prism:

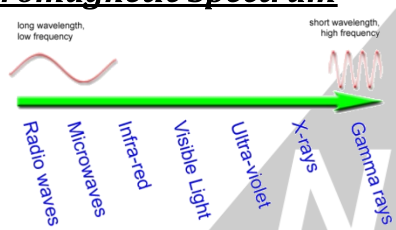
- When light is refracted by a prism, the incidence ray is not parallel to the emergent ray, since the prism's sides are not parallel.



- If a beam of white light is passed through a prism it is dispersed into a spectrum.
- White light is a mixture of colors, and the prism refracts each color by a different amount – red is deviated least & violet most

13.8 Light Spectrum

13.9 Electromagnetic Spectrum



All electromagnetic waves:

- Travel at the speed of light: 3×10^8m/s
- Don't need a medium to travel through (travel through a vacuum)
- Can transfer energy
- Are produced by particles oscillating or losing energy in some way
- Are transverse waves

13.10 Uses

- **Radio waves**: radio and television communications
- **Microwaves:** satellite television and telephones
  - Safety issue: cause internal heating of body tissues
- **Infrared**: electrical appliances (radiant heaters and grills), remote controllers for televisions and intruder alarms
- **X-rays:** medicine (x-ray photography and killing cancer cells) and security
  - Safety issue: is a mutagen, it cause cancer (mutations)
- **Monochromatic:** light of a single wavelength and color (used in lasers)

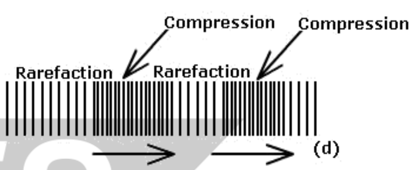
14. Sound

14.1 Production

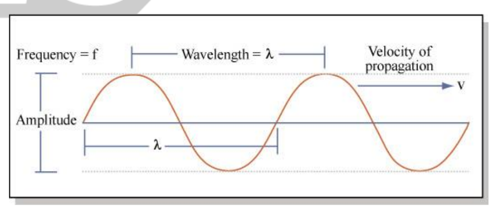
- Sound waves come from a vibrating source e.g. loudspeaker
- As the loudspeaker cone vibrates, it moves forwards and backwards, which squashes & stretches the air in front.
- As a result, a series of compressions (squashes) and rarefactions (stretches) travel out through the air, these are sound waves

14.2 Properties

- Sound waves are **longitudinal**: they have compressions and rarefactions and oscillate backwards and forwards.
- **Humans can hear frequencies between 20 and 20 000Hz.**
- Sound waves need a medium to travel through.
- Ultrasound Waves: high frequency sound waves, medically used to look at structures and organs inside the human body, i.e. to form an image of a fetus in a pregnancy



- Compression: high pressure section of the wave
- Rarefaction: low pressure section of the wave



- The higher the frequency, the higher the pitch.
- The higher the amplitude, the louder the sound

14.3 Speed of Sound

MEDIUM	STATE	SPEED
CONCRETE	Solid	5000 m/s
PURE WATER	Liquid	1400 m/s
AIR	Gas	330 m/s

$$V\ Gas < V\ Liquid < V\ Solid$$

14.4 Experiment: Finding Speed of Sound

- When sound reflects off of a wall, it will come back to you; echo
- If you know the distance between you and the wall, and measure how long it takes for the echo to sound, you can figure out the speed of sound in air.
- Remember to take into account that sound has gone there & back

15. SIMPLE PHENOMENA OF MAGNETISM

15.1 Properties of Magnets

- Has a magnetic field around it
- Has 2 opposite poles (North and South) which exert forces on other magnets. Like poles repel and unlike poles attract.
- Will attract magnetic materials by inducing (permanent or temporary) magnetism in them.
- Will exert little or no force on a non-magnetic material
- The direction of an electric field at a point is the direction of the force on a positive charge at that point

15.2 Induced Magnetism

- Magnets attract materials by inducing magnetism in them; the material becomes a magnet as well.
- The side of the material facing the magnet will become the opposite pole as the magnet.

FERROUS *Magnetic materials*	NON-FERROUS *Non-magnetic materials*
• **IRON** • **NICKEL** • **COBALT**	

15.3 Magnetisation Methods

- A piece of steel becomes permanently magnetized when placed near a magnet, but its magnetism is usually weak.
- It can be magnetized more strongly by stroking it with one end of a magnet
- *Most effective method: place it in a solenoid and pass a large, direct current (d.c.) through the coil.*

15.4 Demagnetisation Methods

- If a magnet is hammered, its atomic magnets are thrown out of line and it becomes demagnetized.
- Heating a magnet to a high temperature also demagnetize it.
- *Most efficient method: place magnet inside a solenoid connected to an alternating current (a.c.) supply.*

15.5 Experiment: Field Lines Around Bar Magnet

The magnetic field lines can be traced on a paper by a compass needle (a tiny magnetic needle).

- The compass needle is first placed near the north pole of magnet.
- The position of poles of needle are marked on paper.
- Then needle is moved to new position such that position of its south pole coincides with previous position of its north pole.
- This process is continued until the needle reaches South Pole.
- By joining these points we get to magnetic line of force.
- Then it is placed at some other position near North Pole and above procedure id repeated.

15.6 Magnetic Properties of Iron and Steel

IRON	STEEL
• Gets magnetized faster but loses its magnetism as soon as inducing magnet is removed. • *High susceptibility but low retentivity* • Use: core in the transformer	• Slow to be magnetized but retains acquired magnetism for a long time. • *Low susceptibility but high retentivity.* Use: making magnets.

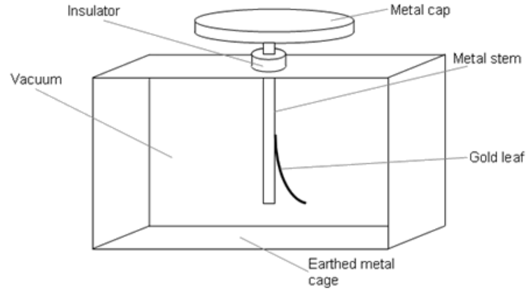
15.7 Permanent Magnets & Electromagnets

PERMANENT MAGNET	ELECTROMAGNET
• Design: hard magnetic material • Use: for applications where magnetism is needed over long periods – fridge doors	• Design: Uses a solenoid to create magnetic field • Use: For applications where magnetic field needs to be turned on & off - scrap metal moving

16. ELECTRICAL QUANTITIES

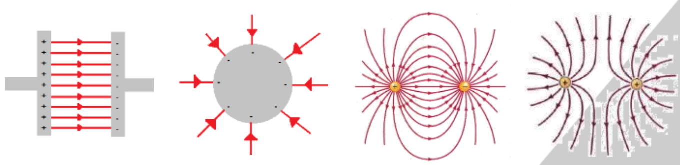
16.1 Electric Charge

- You can detect an electrostatic charge using a leaf electroscope.
  - If a charged object is placed near the cap, charges are induced.
  - The metal cap gets one type of charge (positive or negative) and the metal stem and gold leaf get the other type of charge so they repel each other.



- There are 2 types of charges: positive and negative.
- Unlike charges attract and like charges repel.
- Electric field: region in which electric charge experiences a force
- Conductors: materials that let electrons pass through them.
  - Metals are the best electrical conductors as they have free electrons.
- Insulators: materials that hardly conduct at all.
  - Their electrons are tightly held to atoms and hardly move, but they can be transferred by rubbing
- The SI unit of charge is the Coulomb (C).

16.2 Electric Field Lines



Parallel plates	Point charge	+ve and -ve	+ve and +ve

16.3 Induced Charge

- A charge that "appears" on an uncharged object because of a charged object nearby
- For example if a positively charged rod is brought near a small piece of aluminum foil, electrons in foil are pulled towards rod, which leaves the bottom of the foil with a net positive charge.
- The attraction is stronger than repulsion because the attracting charges are closer than the repelling ones.

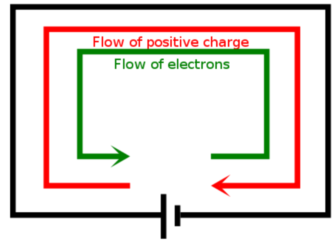
16.4 Current

- Current: a flow of charge, the SI unit is the Ampere (A).
- An ammeter measures the current in a circuit and is connected in series
- Current is a rate of flow of charge.

$$Charge\ (C) = Current\ (A) \times Time\ (s)$$
$$Q = It$$

- Current follows path of least resistance
- The conventional current is the opposite of what actually happens.

Red=conventional current
Green=actual current



- $1\bar{e} = 1.6 \times 10^{-19} C$
- $1C = 6.25 \times 10^{18} \bar{e}$

16.5 Electromotive Force (EMF)

- The maximum voltage a cell can produce is called the electromotive force (EMF), measured in volts.
- When a current is being supplied, the voltage is lower because of the energy wastage inside the cell.
- A cell produces its maximum PD when not in a circuit and not supplying current.

16.6 Potential Difference (P.D)

- Potential difference, or PD for short, is also known as voltage.
- Voltage is the amount of energy the cell gives the electrons it pushes out. Voltage is measured in volts (V) and is measured by a voltmeter (connected in parallel). If a cell has 1 Volt, it delivers 1 Joule of energy to each coulomb of charge (J/C).

$$Voltage = \frac{Energy}{Charge}$$
$$V = \frac{E}{C}$$

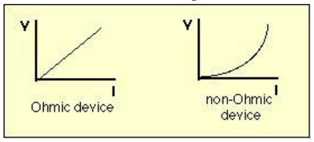
16.7 Resistance

$$Resistance\ (\Omega) = \frac{Voltage}{Current} = \frac{V}{I}$$

Factors affecting resistance:

- Length
  - $R \propto L$
- Cross-sectional area
  - $R \propto \frac{1}{A}$
- Material
  - Better conductor = less resistance
- Temperature
  - For metal conductors higher temperature = more resistance
  - For semi-metal conductors higher temperature

16.8 V-I Characteristics of a Resistor



- Ohm's law states that voltage across a resistor is directly proportional to the current through it. This is only true if the temperature of the resistor remains constant

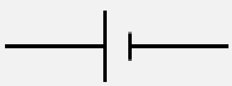
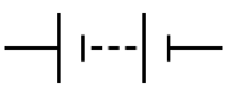
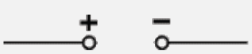
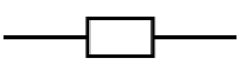
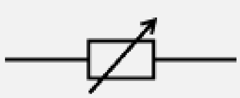
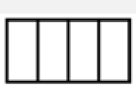
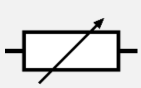
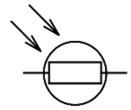
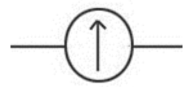
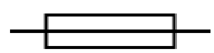
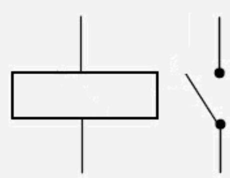
16.9 Electrical Energy

- 1 Watt is 1J/s

$$Electrical\ power = Voltage\ (V) \times Current\ (A)$$
$$P = VI$$
$$Electrical\ energy = Voltage\ (V) \times Current$$
$$E = VIt$$

17. Electrical Circuits

17.1 Circuit Diagrams

COMPONENT	SYMBOL	FUNCTION
Cell		Supplies electrical energy. Larger terminal (left) is positive (+).
Battery		Supplies electrical energy. A battery is more than one cell. Larger terminal (left) is positive (+).
DC Supply		Flows in one direction
AC Supply		Flows in both direction
Switch		Allows current only to flow when the switch is closed
Fixed resistor		Restrict the flow of current.
Variable resistor		Used to control current (by varying the resistance)
Heaters		
Thermistor		Resistor whose resistance varies with temperature
Light-dependent resistors		Resistor whose resistance varies with light intensity
Lamp		Transducer which converts electrical energy to light
Ammeter		Measure current
Voltmeter		Measure voltage
Galvano-meters		Type of sensitive ammeter; instrument for detecting electric current.
Magnetizing Coil		
Transformer		Two coils of wire linked by an iron core. Transformers are used to increase and decrease AC voltages.
Bell		Transducer which converts electrical energy to sound
Fuse		A safety device which will 'blow' (melt) if current flowing through it exceeds specified value, breaking circuit
Relay		An electrically operated switch, e.g. a 9V battery circuit connected to the coil can switch a 230V AC mains circuit (the electromagnet is used to pull away the contacts and vice versa)

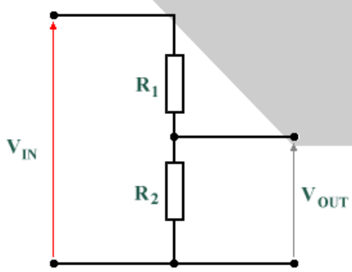
17.2 Series and Parallel Circuits

- The current at any point in a series circuit is the same
- The current splits at each branch in a parallel circuit so the total current is always greater than the current in one branch

- Combining resistors
  - In Series: $R_{Total} = R_1 + R_2$
  - In Parallel: $R_{Total} = \frac{1}{1/R_1 + 1/R_2}$
  - The combined resistance of 2 resistors in parallel is less than that of either resistor by itself
- Advantages of putting lamps in parallel are:
  - If one lamp breaks, the other still works
  - Each lamp gets maximum PD
- In series: PD across the supply = PD across all the components combined
- In parallel: Current across the source = sum of currents in the separate branches

17.3 Potential Divider

- A potential divider divides the voltage into smaller parts.



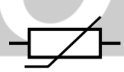
- To find the voltage (at V_{OUT}) we use the following formula:

$$V_{OUT} = V_{IN} \times \left(\frac{R_2}{R_{Total}}\right)$$

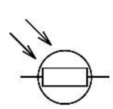
- A variable potential divider (potentiometer) is the same as the one above but using a variable resistor; it acts like a potential divider, but you can change output voltage.

17.4 Input Transducer

- **Thermistor:** input sensor and a transducer. It is a temperature-dependent resistor. At higher temperature there is less resistance.

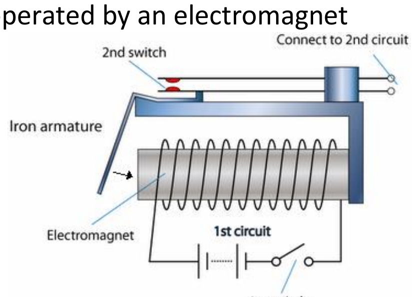


- **Light dependent resistor (LDR):** input sensor and a transducer. When light intensity increases, resistance decreases.

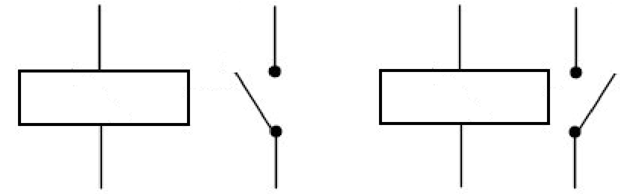


17.5 Relay

- A switch operated by an electromagnet

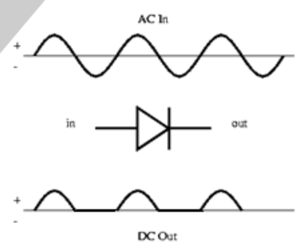


NORMAL CLOSED RELAY	NORMALLY OPEN RELAY
When coil *not energized*, switch is closed, completing circuit	When coil *energized*, switch is closed, completing circuit



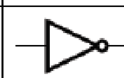
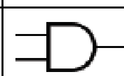
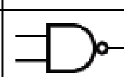
17.6 Diode

- A device that has an extremely high resistance in one direction and a low resistance in the other, therefore it effectively only allows current to flow in one direction
- Forward bias is when the diode is pointing in the direction of the conventional current and reverse bias is the opposite
- It can be used in a rectifier; turns AC current into DC current.



17.7 Digital Electronics

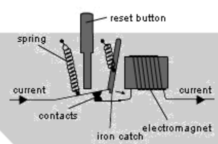
- Analogue uses a whole range of continuous variations to transmit a signal.
- Digital signals use only 2 states, on and off.
- Logic gates are processors that are circuits containing transistors and other components.

Gate	Symbol	Input A	Input B	Output
NOT Gate		0 1	None	1 0
AND Gate		0 0 1 1	0 1 0 1	0 0 0 1
OR Gate		0 0 1 1	0 1 0 1	0 1 1 1
NAND Gate		0 0 1 1	0 1 0 1	1 1 1 0
NOR Gate		0 0 1 1	0 1 0 1	1 0 0 0

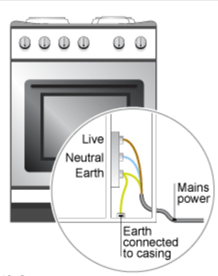
18. Dangers of Electricity

18.1 Hazards

- **Damaged insulation:** contact with the wire (live wire especially) due to gap in the insulation causes electric shock which can cause serious injury or shock.
- **Overheating of cables:** when long extension leads are coiled up, they may overheat. The current warms the wire, but the heat has less area to escape from a tight bundle. This might cause a fire.
- **Damp conditions:** water can conduct a current, so if electrical equipment is wet someone might get electrocuted

FUSE	CIRCUIT BREAKER
	
A fuse protects a circuit. Thin piece of wire which overheats and melts if current is too high. It is placed on the live wire before the switch. This prevents overheating and catching fire. A fuse will have a specific current value (e.g. 13a) so when choosing a suitable fuse you must use the one above minimum value but less than maxiumum value	An automatic switch which if current rises over a specified value, the electromagnet pulls the contacts apart, breaking the circuit. The reset button is to rest everything. It works like a fuse but is better because it can be reset.

- **Benefits of Earthing a Metal Case:**
  - Many electrical appliances, have metal cases, the earth wire creates a safe route for current to flow through, if live wire touches casing
  - Earth terminal connected to metal casing, so the current goes through earth wire instead of causing an electric shock.
  - A strong current surges through earth wire because it has very low resistance
  - This breaks the fuse and disconnects the appliance

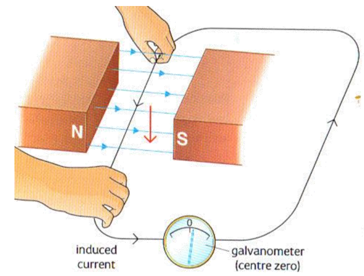


19. Electromagnetic Effects

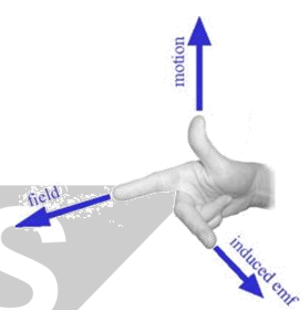
19.1 Electromagnetic Induction

Wire passed across a magnetic field:

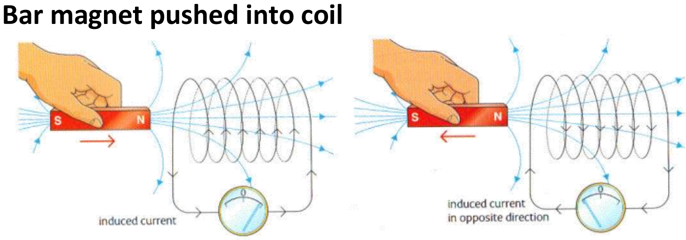
- If a wire is passed across a magnetic field, a small EMF is induced,
- If the wire forms part of a complete circuit, the EMF makes a current flow and this can be detected using a galvanometer.



- The EMF induced in a conductor is proportional to the rate at which the magnetic field lines are cut by the conductor.
- The induced EMF can be increased by:
  - moving the wire faster
  - using a stronger magnet
  - Increasing length of wire in magnetic field, e.g. looping the wire through the field several times.
- The current and EMF direction can be reversed by:
  - moving the wire in the opposite direction
  - turning the magnet round so that the field direction is reversed
- **Fleming's right-hand rule** gives the current direction:

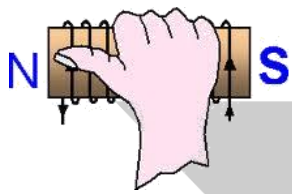


Bar magnet pushed into coil



- The induced EMF (and current) can be increased by:
  - moving the magnet faster
  - using a stronger magnet
  - increasing the number of turns in the coil
- If the magnet is pulled away, the direction of the induced EMF (and current) is reversed

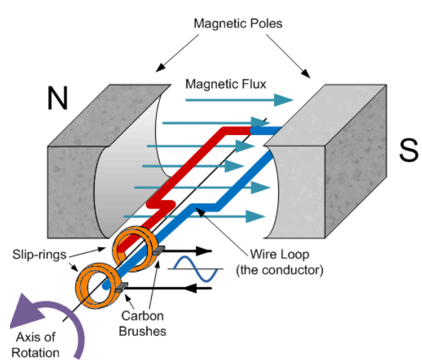
- Using South pole instead of North pole reverses direction of induced EMF (and current)
- If the magnet is held still, there is no EMF
- An induced current always flows in a direction such that it opposes the change which produced it.
- When a magnet is moved towards a coil the pole of the coil and magnet next to each other are the same.
- When the magnet is moved away the poles are opposite (opposite poles attract).
- The pole-type (north or south) is controlled by the direction in which the current is induced.
- The direction of the current is given by the **right-hand grip rule:**



- The fingers point in the conventional current direction and the thumb gives the North Pole.

19.2 A.C. Generator

- The oil is made of insulated copper wire and is rotated by turning the shaft; the slip rings are fixed to the coil and rotate with it.
- The brushes are 2 contacts which rub against the slip rings and keep the coil connected to the outside part of the circuit, usually made of carbon.
- When the coil is rotated, it cuts magnetic field lines, so an EMF is generated, which makes a current flow.
- Each side of the coil travels upwards then downwards then upwards etc. so the current flows backwards then forwards then backwards etc. so it is an alternating current.
- The current is maximum when the coil is horizontal since field lines are being cut at the fastest rate and 0 when the coil is vertical, since it is cutting NO field lines.
- The EMF can be increased by:
  - increasing the number of turns on the coil
  - increasing the area of the coil
  - using a stronger magnet
  - rotating the coil faster



19.3 Transformers

- AC currents can be increased or decreased by using a transformer.
- Consists of a primary coil, a secondary coil and an iron core.
- The iron core gets magnetized by the incoming current and this magnetism then creates a current in the leaving wire.
- The power is the same on both sides (assume= 100% efficiency).
- You can figure out number of coils and the voltage with:

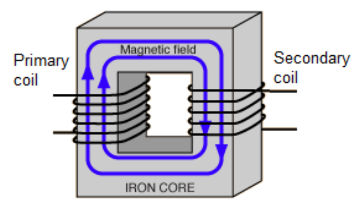
$$\frac{\textit{Output voltage}}{\textit{Input voltage}} = \frac{\textit{Turns on output coil}}{\textit{Turns on input coil}}$$

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$\textit{Input voltage} \times \textit{input current} = \textit{output voltage} \times \textit{output current}$$

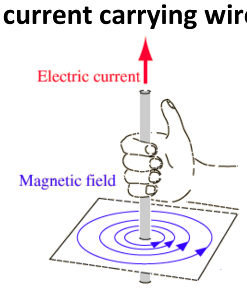
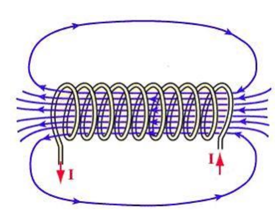
$$V_1 \times I_1 = V_2 \times I_2$$

- When magnetic field is changed across the primary coil by connecting it with A.C. an e.m.f. induces across the secondary coil.



- The iron core channels the alternating field through the secondary coil, inducing an alternating e.m.f. across it.
- A **step-up** transformer increases the voltage and a **step-down** transformer decreases it.
- Transformers used to make high voltage AC currents.
- Since power lost in a resistor $P = I^2 \times R$, having a lower current will decrease the power loss.
- Since transmission cables are many kilometres long they have a lot of resistance, so a transformer is used to increase the voltage and decrease the current to decease power lost.
- The advantages of high-voltage transmission:
  - less power lost
  - thinner, light, and cheaper cables can be used since current is reduced

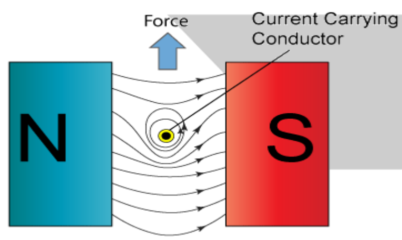
19.4 Electromagnetic Effect of a Current

Magnetic field around a current carrying wire	**Magnetic field around a current carrying solenoid**
	

- Increasing the current increases the strength of the field
- Increasing the number of turns of a coil increases the strength.
- Reversing the current direction reverses the magnetic field direction (right-hand rule).
- Magnetic effect of current is used in a relay and a circuit breaker

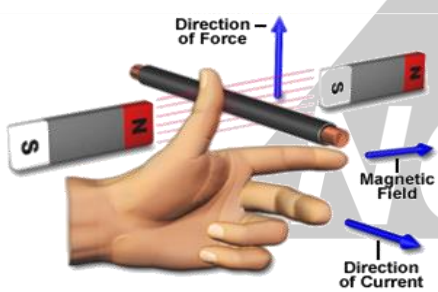
19.5 Force on a Current-Carrying Conductor

- If a current carrying conductor is in a magnetic field, it warps the field lines.
- The field lines from the magnet want to straighten out naturally.
- This causes a catapult like action on the wire creating a force

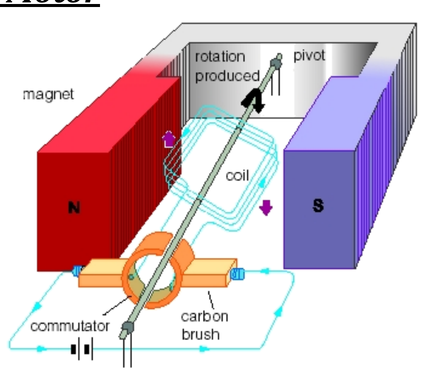


Catapult Field

- If you reverse current, you will reverse direction of force
- If you reverse direction of field, you will reverse direction of force.
- The direction of the force, current or magnetic field is given by **Fleming's left-hand rule:**



19.6 D.C. Motor



- When a current-carrying coil is in a magnetic field, it experiences a turning effect.
- A DC motor runs on a direct current.
- The coil is made of insulated copper wire and is free to rotate between the poles of the magnet.
- The commutator (split-ring) is fixed to the coil and rotates with it.
- When the coil overshoots the vertical, the commutator changes direction of the current through it, so the forces change direction and keep the coil turning.
- The brushes are two contacts which rub against the commutator and keep the coil connected to battery, usually made of carbon
- The max. turning effect is when the coil is horizontal.
- There is no force when the coil is vertical but it always overshoots this position

TURNING EFFECT INCREASED BY:	REVERSING ROTATION CAN BE DONE BY:
• Increasing the current • Using a stronger magnet • Increasing length of coils: ○ Increasing no. of coils ○ Increasing area of coil	• Reversing the battery • Reversing the poles

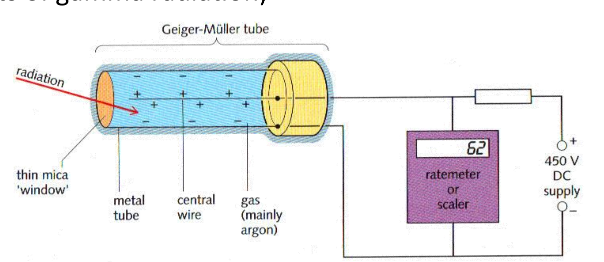
20. Radioactivity

20.1 Direction of Radioactivity

- **Background radiation:** small amount of radiation around us all time because of radioactive materials in the environment. It mainly comes from natural sources such as soil, rocks, air, building materials, food and drink – and even space.

Geiger-Müller (GM) tube (detects α, β and γ)

- The 'window' is thin enough for alpha particles to pass through.
- If an alpha particle enters the tube, it ionizes gas inside.
- This sets off a high-voltage spark across the gas and a pulse of current in the circuit.
- A beta particle or gamma radiation has the same effect.
- It can be connected to a rate meter (tells the counts per seconds) or a scaler (tells total number of particles or bursts of gamma radiation)



20.2 Characteristics of 3 Kinds of Emissions

- Radioactive emissions occur randomly over space & time

	ALPHA (α)	BETA (β)	GAMMA (γ)
NATURE	Helium nucleus (2 protons and 2 electrons)	One high speed electron	Electro-magnetic radiation
CHARGE	+2	-1	none
PENETRATION	Stopped by paper	Stopped by aluminum	Only reduced by lead
EFFECT FROM FIELDS	Deflected	Very deflected	Not deflected
IONIZING EFFECT	Very strong	Weak	Very weak
SPEED	$^{1}/_{10}\ v\ of\ light$	$^{9}/_{10}\ v\ of\ light$	$v\ of\ light$

20.3 Radioactive Decay

- **Radioactive decay:** A radioisotope (unstable arrangement of neutrons and protons) is altered to make a more stable arrangement.
- The parent nucleus becomes a daughter nucleus and a particle (decay products).

Alpha decay:

- An element with a proton number 2 lower and nucleon number 4 lower, and an alpha particle is made (2p + 2n)

e.g. Radium-226 nucleus → Radon-222 + helium-4 nucleus

$$^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\text{He}$$

Beta decay:

- A neutron changes into a proton, an electron and an antineutrino so an element with the same nucleon number but with a proton number 1 higher e.g.

e.g. iodine-131 → xenon-131 + antineutrino + beta particle

$$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}\beta + {}^{0}_{0}\text{v}$$

Gamma emission:

- Gamma emission by itself causes no change in mass number or atomic number; they just emit energy
- Some isotopes do not change in mass or atomic number however they emit energy as their particles rearrange themselves to become more stable

20.4 Half Life

- **Half-life of a radioisotope:** is the time taken for half the nuclei present in any given sample to decay.
- Some nuclei are more stable than others

20.5 Safety Precautions

- Radioactive material is stored in a lead container
- Picked up with tongs, not bare hands
- Kept away from the body and not pointed at people
- Left out of its container for as short a time as possible

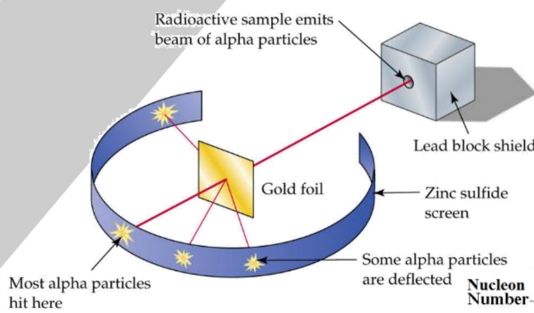
20.6 Atomic Model

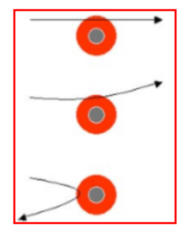
Atoms consist of:

- **Nucleus:** central part of atom made of protons (positively charged) and neutrons. These two types of particles are called nucleons. They are bound together by the strong nuclear force.
- **Electrons:** almost mass-less particles which orbit nucleus in shells

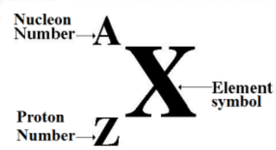
20.7 Rutherford's Experiment

- Thin gold foil is bombarded with alpha particles, which are positively charged.
- Most passed straight through, but few were repelled so strongly that they were bounced back or deflected at large angles.
- Rutherford concluded that the atom must be largely empty space, with its positive charge and most of its mass concentrated in a tiny nucleus.





20.8 Nucleus



- The nucleus is composed of protons and neutrons.
- **Proton number:** number of protons in an atom
- **Nucleon number:** the number of nucleons (protons + neutrons) in an atom

20.9 Isotopes

- **Isotope:** atoms of the same element that have different numbers of neutrons e.g. Carbon 12 and Carbon 14.
- There are non-radioactive isotopes and radio-isotopes.
- Radio isotopes are unstable atoms, which break down giving radiation
- **Medical use:** cancer treatment (radiotherapy) – rays kill cancer cells using cobalt-60
- **Industrial use:** to check for leaks – radioisotopes (tracers) added to oil/gas. At leaks radiation is detected using a Geiger counter.
- **Archaeological use:** carbon 14 – used for carbon dating

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